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Relative strength of the 1999 and 2000 year-classes, from nearshore surveys of demersal age 0 & 1 Atlantic cod in 3KL and in Newman Sound, Bonavista Bay

Importance relative des classes d'âge de 1999 et de 2000, d'après des relevés côtiers de la morue démersale de 0 et 1 an dans 3KL et dans le bras Newman (baie de Bonavista)

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Abstract

From 1959 to 1964 and 1992 to 1997 (i.e., 1990s), demersal age 0 Atlantic cod (*Gadus morhua*) in the nearshore (<10 m deep) were surveyed by seine from St. Mary's Bay to Notre Dame Bay, Newfoundland during the Fleming survey, conducted annually in September and October. In the absence of a coastwide Fleming survey in 1998-2000, we conducted a qualitative assessment of the strength of four 1997-2000 year-classes. Our assessment was based on abundance of demersal age 0 and age 1 Atlantic cod sampled at 6 - 13 nearshore sites in Newman Sound, Bonavista Bay in five summer-autumn periods during 1995-2000. Sampling techniques and collection dates for the Fleming survey and Newman Sound study were similar. Therefore, cod abundances in the two studies were comparable, albeit at different geographic scales. Abundance trends of age 0 and 1 cod covaried between the studies in 1995 and 1996, when both were conducted concurrently, suggesting that abundances of juvenile cod in Newman Sound mirrored those observed in the spatially broader Fleming survey. In 1997, age 0 abundance in the Fleming survey was the highest observed in the 1990s, leading to the prediction that age 1 cod would be high the following year. High age 1 abundance in 1998 compared to 1995 and 1996 in Newman Sound supported this prediction. Compared with the historical low in 1996 observed in both studies, age 0 abundance was 10 times higher in 1998 and 40 times higher in 1999. These results suggest that the 1997, 1998, and 1999 year classes should be strong compared to those in 1995 and 1996. Analysis of length frequency data collected from July to November in Newman Sound indicated that age 0 Atlantic cod settled in the nearshore in two distinct recruitment pulses in "good years" - i.e., 1998 and 1999 - the first pulse arriving in early August, the second in late September. In "bad years" - i.e., 1995 and 1996 - only the second of these pulses was evident. The length frequency data also suggest that the pulse structure may remain intact through the first winter and appears to be detectable in age 1 cod the subsequent year. In 2000, we (Gregory et al. 2000) predicted that the 1999 year class of Atlantic cod will prove to be the strongest since the 1992 moratorium. Catches of the 1999 year class in 2000 as age 1 fish, support this prediction. Age 1 Atlantic cod in Newman Sound in 2000 were the highest we have ever recorded at these sites. In contrast to 1997-1999, we anticipate that the 2000 year class will be weak, based on nearshore densities of age 0 Atlantic cod in Newman Sound. Densities of age 0 Atlantic cod were consistently low throughout much of the season, and were comparable to 1996, the poorest year class on record in three independent surveys of age 0 abundance off the northeast Newfoundland coast.

Résumé

De 1959 à 1964 et de 1992 à 1997 (années 1990), un relevé à la senne des morues de l'Atlantique (*Gadus morhua*) démersales d'âge 0 se trouvant à proximité de la côte (<10 m de profondeur) a été effectué de la baie St. Mary's à la baie Notre Dame (Terre-Neuve), pendant le relevé Fleming qui est réalisé chaque année en septembre et octobre. Le relevé Fleming n'ayant pas été effectué à la grandeur de la côte de 1998 à 2000, nous avons procédé à une évaluation qualitative de l'importance des classes d'âge de 1997, 1998, 1999 et 2000 en nous fondant sur l'abondance des morues démersales d'âges 0 et 1 prélevées dans 6 à 13 sites voisins de la côte dans le bras Newman (baie de Bonavista), à l'été et à l'automne de 1995 à 2000. Les techniques et les dates de prélèvement du relevé effectué dans le bras Newman étaient semblables à celles du relevé Fleming. Les données d'abondances obtenues dans ces deux relevés étaient donc comparables, bien qu'elles portaient sur des échelles spatiales différentes. Pour 1995 et 1996, nous avons observé une covariance entre les abondances des morues d'âges 0 et 1 observées lors des deux relevés effectués simultanément, ce qui porte à croire que l'abondance des morues juvéniles notée dans le bras Newman correspondait à celle observée au cours du relevé Fleming, de plus grande envergure spatiale. En 1997, l'abondance des morues d'âge 0 notée lors du relevé Fleming était la plus élevée des années 1990, ce qui portait à prévoir que celle des poissons d'âge 1 serait élevée l'année suivante. De fait, l'abondance élevée des morues d'âge 1 en 1998 dans le bras Newman comparativement à celles des années 1995 et 1996, confirme cette prévision. En 1998 et en 1999, les abondances des morues d'âge 0 étaient respectivement 10 fois supérieure et 40 fois supérieure aux valeurs les plus faibles jamais enregistrées qui ont été obtenues lors des deux relevés en 1996. Ces résultats portent à croire que les classes d'âge de 1997, de 1998 et de 1999 devraient être importantes par rapport à celles de 1995 et de 1996. L'analyse des fréquences des longueurs obtenues de juillet à novembre dans le bras Newman montre que les morues d'âge 0 se sont établies dans la zone côtière en deux pointes de recrutement distinctes au cours des « bonnes » années (1998 et 1999), la première pointe arrivant au début d'août, et la seconde, à la fin septembre. Lors des « mauvaises » années (1995 et 1996), seule la seconde de ces pointes était décelable. Les fréquences des longueurs indiquent aussi que cette structure des pointes de recrutement peut demeurer intacte après le premier hiver et être décelable chez les morues d'âge 1 l'année suivante. En 2000, nous (Gregory et al., 2000) avons prévu que la classe d'âge de 1999 serait la plus importante depuis l'imposition du moratoire, en 1992. Le nombre de morues de cette classe d'âge capturées en 2000 à l'âge d'un an dans le bras Newman confirme cette prévision : il s'agissait de la valeur la plus élevée que nous n'ayons jamais enregistrée pour ces sites. Selon les densités de morues d'âge 0 trouvées près de la côte dans le bras Newman, nous prévoyons que la classe d'âge de 2000 sera faible, contrairement aux classes d'âge de 1997, de 1998 et de 1999. En effet, ces densités de morues d'âge 0 étaient systématiquement faibles durant la plus grande partie de la saison et elles se comparaient aux valeurs de 1996, lorsque trois relevés indépendants ont montré que l'abondance des morues d'âge 0 était la plus faible jamais enregistrée.

Introduction

It has been shown, at least for the 1990's, that age 0 and age 1 Atlantic cod in 3KL (Northeast Newfoundland Shelf) are distributed predominantly in inshore waters (Dalley & Anderson 1997). Within these inshore waters during autumn, age 0 cod are most common in shallow water in the nearshore (<10 m deep - Methven & Schneider 1998, Gregory et al. in prep.). The Fleming surveys (1959 - 64, Lear et al. 1980; 1992-97, e.g., Methven et al. 1998) have historically sampled nearshore abundances of age 0-2 Atlantic cod, with the objective of assessing relative year-class strength. These surveys have generally been successful at predicting the relative strength of adjacent cohorts through the first years of life (Schneider et al. 1997).

The 1997 Fleming survey (Methven et al. 1998) reported the highest abundance of age 0 cod in the nearshore during the 1992 to 1997 period. However, the success (or failure) of the 1997 year-class could not be assessed directly the survey has not been conducted since that year.

Fortunately, we have access to nearshore abundance data similar to the Fleming time series in a small area within the region sampled annually by that survey. In Fall 1995, an investigation of the adundance of age 0 cod and their association with nearshore habitat types was initiated in Newman Sound, Bonavista Bay (Gotceitas et al. 1996). The 1995 study was followed by similar efforts in 1996-1999 (Gregory et al. 1997, 1998, 1999). These studies showed that the nearshore of Newman Sound represents a significant nursery area for demersal age 0 Atlantic cod. The Newman Sound studies were conducted using the same sampling techniques as the Fleming surveys; collection dates also overlapped. Therefore, the abundance data of the two surveys during the period of study were comparable, albeit at different spatial scales.

In this study, we qualitatively assessed the relative strength of the 1999 and 2000 year-classes based on abundance of demersal age 0 and age 1 Atlantic cod in the nearshore in Newman Sound, Bonavista Bay in summer and fall 2000. We compared abundances of age 0 and age 1 Atlantic cod in Newman Sound in 2000 to previous years (1995, 1996, 1998 and 1999), linking interannual abundance trends to those demonstrated in the Fleming surveys (1992 - 97). We show that interannual trends between the Newman Sound data and the larger scale Fleming survey were consistent. This consistency allowed us to conclude two things: first, the 1998 and 1999 year-classes were relatively stronger than the 1995 and 1996 year-classes; and second, the strong 1997 year-class predicted as a result of the 1997 Fleming survey (Methven et al. 1998) was supported. We also present evidence that links age 0 abundance to temporal recruitment patterns within years. We suggest that in years of relatively higher recruitment, settlement occurs in more than one recruitment pulse (Methven and Bajdik 1994, Grant and Brown 1998) several weeks apart; in years of relatively poor recruitment, recruitment is often limited to a single pulse. We also show that despite a detectable multiple pulse structure, the 2000 year-class appears destined to be weak relative to those of the late 90's.

Methods

Sites sampled during the 1992 - 1997 Fleming surveys have been described in previous reports (e.g., Methven et al. 1998). In the 1990's, the Fleming survey was conducted at between 37 - 45 nearshore sites extending from St. Mary's Bay in the south to Notre Dame Bay in the north from 19 September to 27 October. In Bonavista Bay, sampling during the Fleming survey was generally 5 - 9 October (18 October in 1997).

Newman Sound seine sites (Fig. 1), described in Gregory et al. (1997), were selected on the basis of sampling logistics, and were similar to those of the Fleming survey (Lear et al. 1980). To maintain consistency among years, we have presented age 0 and age 1 abundance data from four of these sites (#1, 2, 3, and 6, Fig. 1), which were in common among our field programs in all years, 1995 - 2000 in Newman Sound. For comparison with the Fleming survey data, we analyzed data from Newman Sound which had been collected only during the first two weeks of October during these years. In order to investigate seasonal growth and timing of recruitment pulses, we examined sizes of Atlantic cod captured and measured from all sites sampled in Newman Sound - September to November, 1995 (6 sites) and July to November in 1996 (9 sites), 1998-2000 (13 sites).

Both the Fleming survey and Newman Sound studies used the same sampling techniques. Fish samples were collected using a 25 m beach seine - wings and belly 19 mm stretch mesh, codend 9 mm stretch mesh bag; 24.4 m headrope, 26.2 m footrope; 75 cm long and 25 mm diameter aluminum poles on each wing served to maintain the spread between the headrope and footrope. The net was deployed from a 6 m boat at a distance of 55 m from the shore, and then retrieved by two individuals standing 16 m apart on the shore. The seine was pulled along the bottom and sampled the lowest 2 m of the water column. Deployed in this manner, the net samples approximately 880 m^2 of the bottom. Less than 5% of all fish enclosed by the net are missed or escape (D. Ings, unpublished data).

All fish collected were identified and counted. Juvenile cod were assigned to tentative age groups based on previously established age-length relationships in Newfoundland waters in late autumn (age 0: $\leq$ 10 cm SL [standard length], age 1: 10 to 20 cm SL, and age 2: 20 to 30 cm SL - Dalley & Anderson 1997).

Results and Discussion

We observed good correspondence of age 0 and age 1 Atlantic cod abundance trends in 1995 and 1996 between the Fleming survey and the Newman Sound study. In both studies, 1996 showed the lowest age 0 abundance among years (Fig. 2). Newman Sound abundance in 1996 was only 26% of that in 1995; in comparison, Fleming survey abundance in 1996 was 51% of that in 1995. Similarly, age 1 abundance was higher in 1996 than it had been in 1995 in both the Fleming survey (2.0 times higher) and in Newman Sound (2.4 times higher) data sets (Fig. 3). The results of the 1997 Fleming survey led Methven (1998) to predicted that age 1

abundance in 1998 would be higher than in previous years of the Fleming survey in the 1990s. Age 1 abundance observed in Newman Sound in 1998 was higher than in 1995 and 1996 qualitatively supporting this prediction (Fig. 3). Age 0 Atlantic cod abundance in Newman Sound was over an order of magnitude higher in 1998 and 40-times higher in 1999 than in 1996. Abundance of age 0 Atlantic cod in 1996 was the lowest recorded in three independant prerecruit studies in the 1990s (1992-97 Fleming - Methven 1998, 1992-99 NE Newfoundland Shelf - Dalley et al. 2000, 1995-2000 Newman Sound - this study). We suggest that the 1998 and 1999 year-classes will be strong relative to 1995 or 1996 year-classes, with the 1999 year-class being the strongest since the implementation of the 1992 moratorium.

Age 0 Atlantic cod appear to recruit (=settle) into nearshore habitats in a recruitment pattern consisting of a number of settlement pulses each year. Analysis of size distribution of age 0 Atlantic cod collected July to November in Newman Sound indicated that age 0 cod settled in only a single recruitment pulse in 1996 (Fig. 4). Similarly, we identified only a single Atlantic cod recruitment pulse in 1995 (Gotceitas et al. 1996), although sampling in Newman Sound only started in late September that year, making definitive statements regarding pulse structure somewhat tenuous. In contrast, in both 1998 (Fig. 5) and 1999 (Fig. 6) age 0 Atlantic cod recruited to the nearshore in two distinct recruitment pulses - the first arriving in August, the second in late September. In 1998, the first pulse was the strongest, whereas the two pulses were equally weighted in 1999 (Fig. 6). In 2000, recruitment to the nearshore was late (September) compared to previous years (usually August – 1996-1999) and there was weak evidence of multiple modes in the length frequency (Fig. 7). Overall abundances in 2000 were low - only slightly higher than 1996, the poorest year for which we have such data from the Newman Sound sites (Fig. 2 & Fig 7). In Newman Sound, there was only one recruitment pulse in both 1995 (Gotceitas et al. 1996) and 1996 (Fig. 8), which were weak years for age 0 abundance overall. In contrast, there were two pulses in 1998 (Fig. 9) and 1999 (Fig. 10) - years of comparatively high age 0 abundance. The pulses were distinctly separated in time in 1998, but less so in 1999. In 2000, there was evidence of multiple recruitment pulses in as many as four separate "events" (Fig. 11).

The pulse structure established for age 0 cod in any given year appears to be maintained in the size structure of age 1 cod in the subsequent year. Evidence of a multiple pulse recruitment pattern was present in both 1996 (Fig. 8) and 1998 (Fig. 9). However, the evidence was especially compelling in 1999 (Fig. 10) when we examined data on the same year-class (1998) in two consecutive years - as age 0 in 1998 (Fig. 9) and as age 1 in 1999 (Fig. 10). The two pulses of the 1999 year class although readily apparent, were only weakly separated in time and size frequency (Fig. 10), possibly explaining why the pulse structure among age 1 Atlantic cod in 2000 was poorly defined (Fig. 11).

Age 1 Atlantic cod density was the highest in 2000 among the surveyed years (Fig. 3). This comparison was done specifically to correspond to the sampling interval of the Fleming survey (i.e., early October). When compared among years throughout the autumn period, average age 1 catch per seine haul (minimum 48 seine hauls) in was approximately 2 – 8 times higher in 2000 (Fig. 12).

The ecological implications of multiple recruitment pulses on year-class strength has yet to be determined. The data in this study suggest that a complex pulse structure (e.g., two or more modes) may signal a relatively good recruitment year compared to a simple pulse structure (e.g., one mode). From genetic evidence, we do know that different stock components contributed differentially to each of these pulses in 1999 (Beacham et al. 2000). We do not yet know if the multiple recruitment patterns we observed in Newman Sound are restricted to individual sites. However, we do know that similar recruitment patterns occur annually at other sites along the northeast Newfoundland coast (Methven & Bajdik 1994, Grant & Brown 1998) suggesting that these observations reflect broader geographic phenomena. Although the ecological implications of complex recruitment pulse structure remain to be worked out, these implications could be large. Size-selective mortality factors should effect differential survival between individuals from different recruitment pulses (Sogard 1997).

Based on the results of this study, we make the following conclusions:

- we reinforce our prediction from 2000 (Gregory et al. 2000) that the 1999 year class will be strong relative to other year classes of our time series, now including the 2000 year class;
- we continue to support the predictions of Methven et al. (1998) that the 1997 year-class will be strong relative to 1995 and 1996 and now 2000;
- we predict that the 2000 year-class will be weak, and will possibly be as low as the 1996 year-class.

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Figures

Figure 1. Location of sampling sites and the nearshore habitat in Newman Sound, Bonavista Bay, July to November 1995-2000.

Figure 2. Mean age 0 Atlantic cod abundance (mean set^{-1}) caught by beach seine in the Fleming survey 1959-64 and 1992-97, St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2000 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

Figure 3. Mean age 1 Atlantic cod abundance (mean set^{-1}) caught by beach seine in the Fleming survey 1959-64 and 1992-97, St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2000 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

Figure 4. Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound, Bonavista Bay, July - November 1996.

Figure 5. Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound, Bonavista Bay, July - November 1998.

Figure 6. Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound, Bonavista Bay, July - November 1999.

Figure 6. Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound, Bonavista Bay, July - November 2000.

Figure 8. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July- November, 1996 and their potential age and recruitment pulse structure.

Figure 9. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July- November, 1998 and their potential age and recruitment pulse structure.

Figure 10. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July- November, 1999 and their potential age and recruitment pulse structure.

Figure 11. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July- November, 2000 and their potential age and recruitment pulse structure.

Figure 12. Age 1 Atlantic cod mean catch per seine set in the autumn (mid-September to end-November) during 1995-2000.

Figure 1. Location of sampling sites and nearshore habitat in Newman Sound, Bonavista Bay July to November 1995-2000.

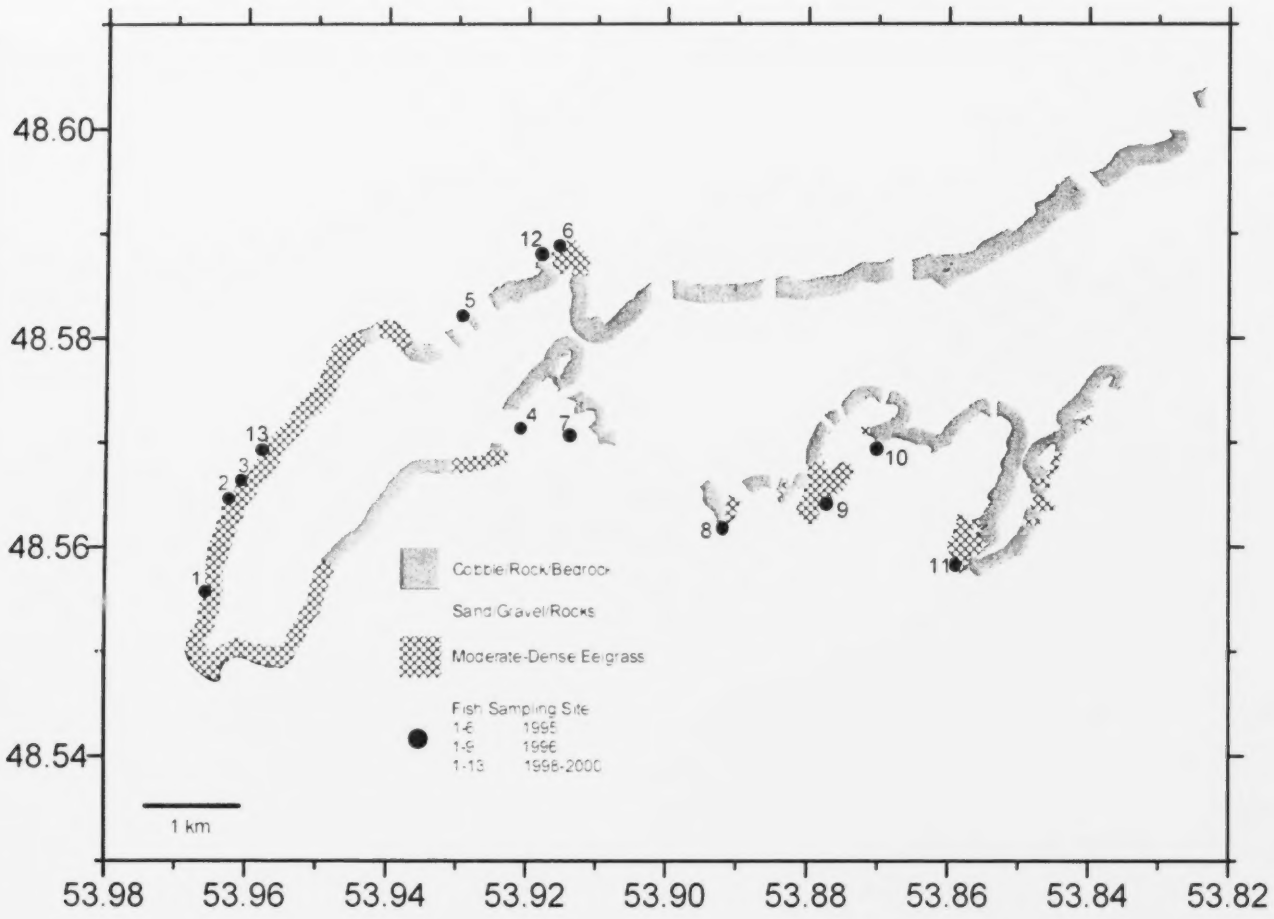

Figure 2. Mean age 0 Atlantic cod abundance (mean/set) caught by beach seine in the Fleming survey 1959-64 and 1992-97, St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2000 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

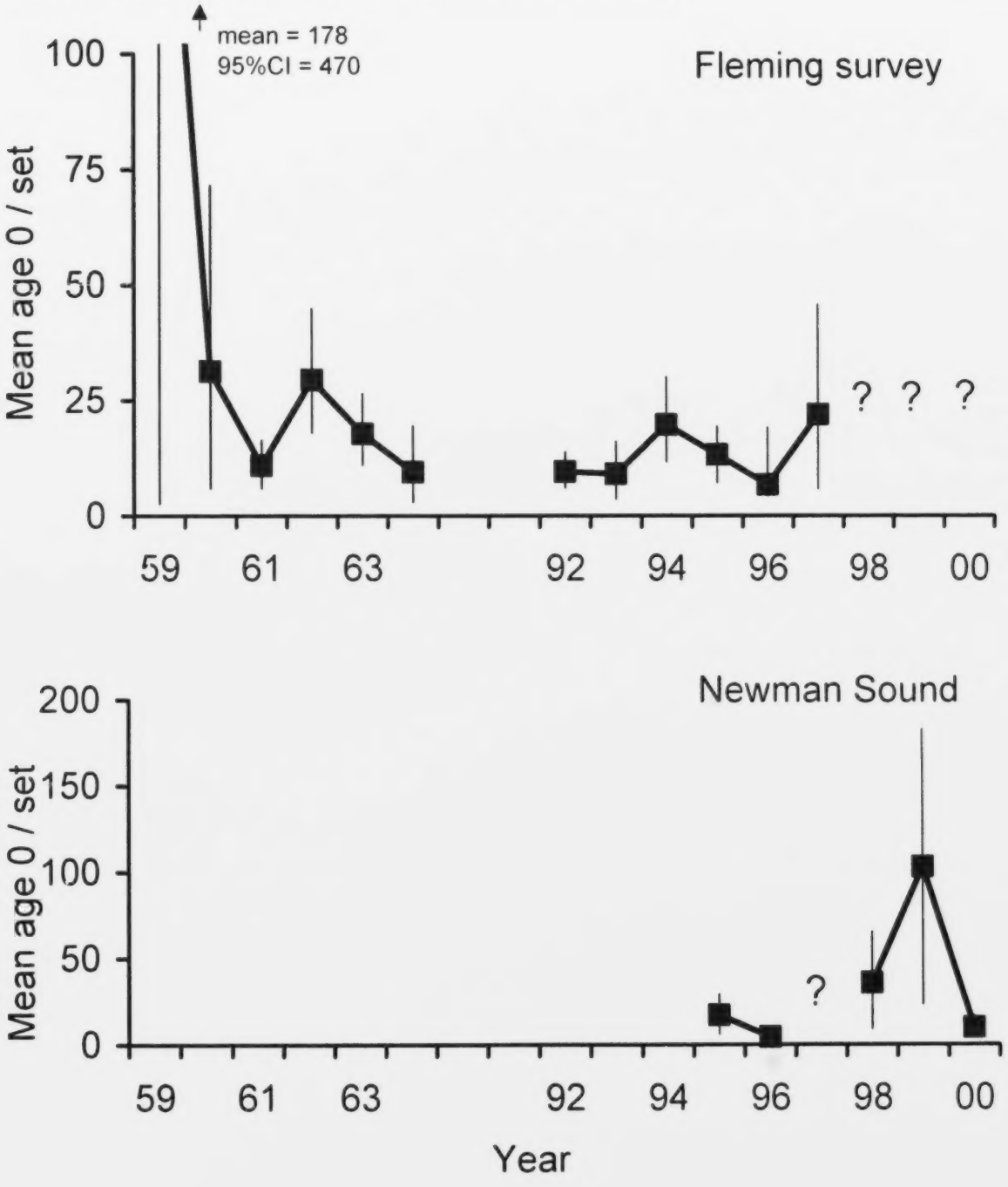

Figure 3. Mean age 1 Atlantic cod abundance (mean/set) caught by beach seine in the Fleming survey 1992-97. St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2000 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

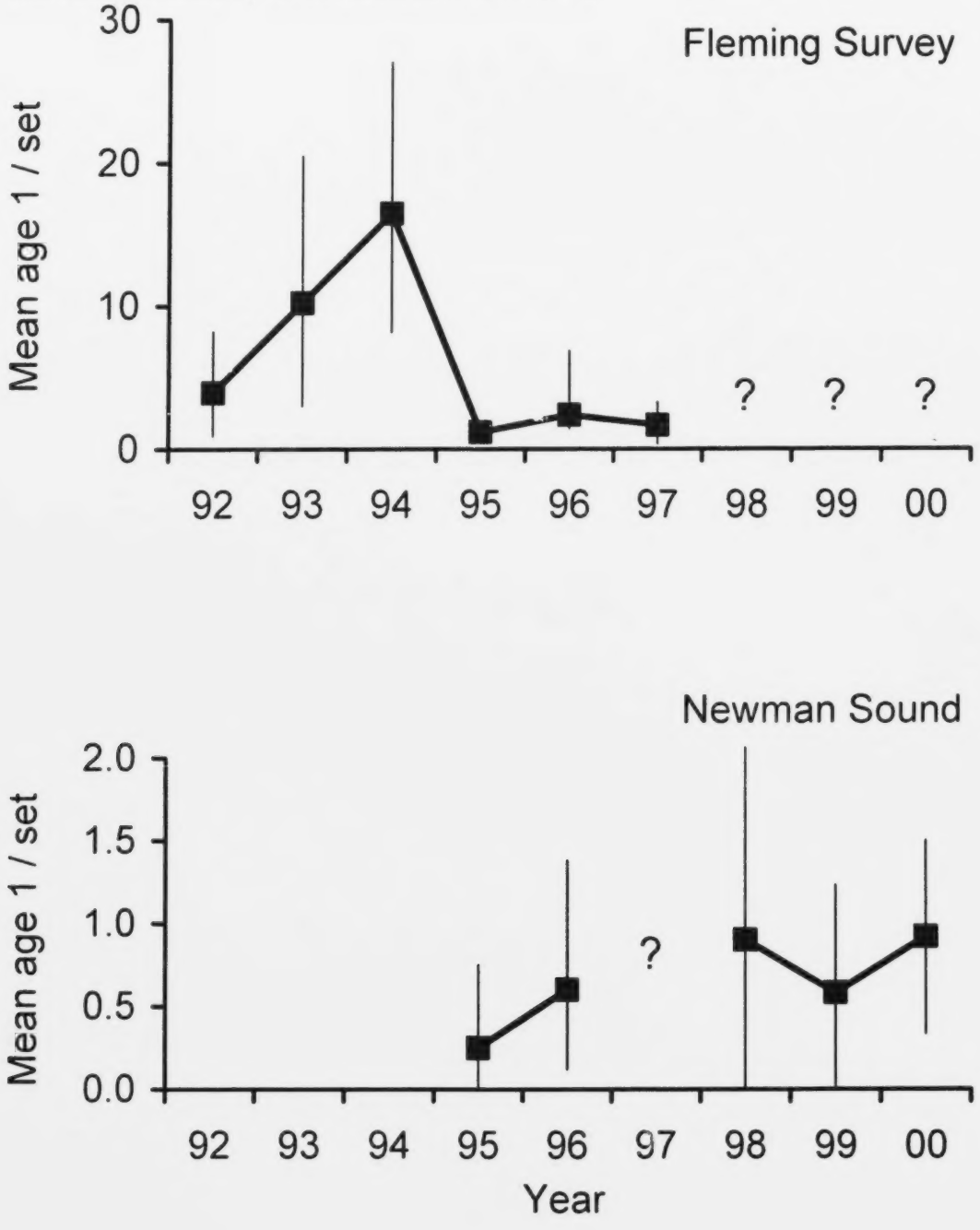

Figure 4. Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound Bonavista Bay, July - November 1996

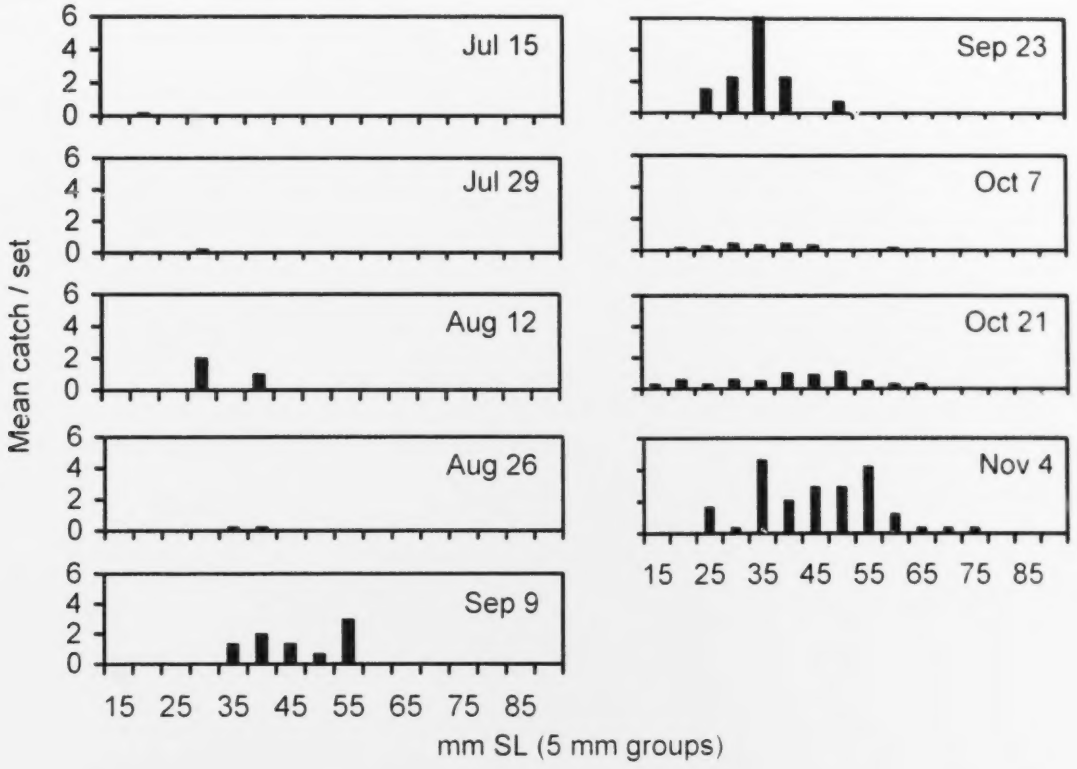

Figure 5 Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound Bonavista Bay, July - November 1998

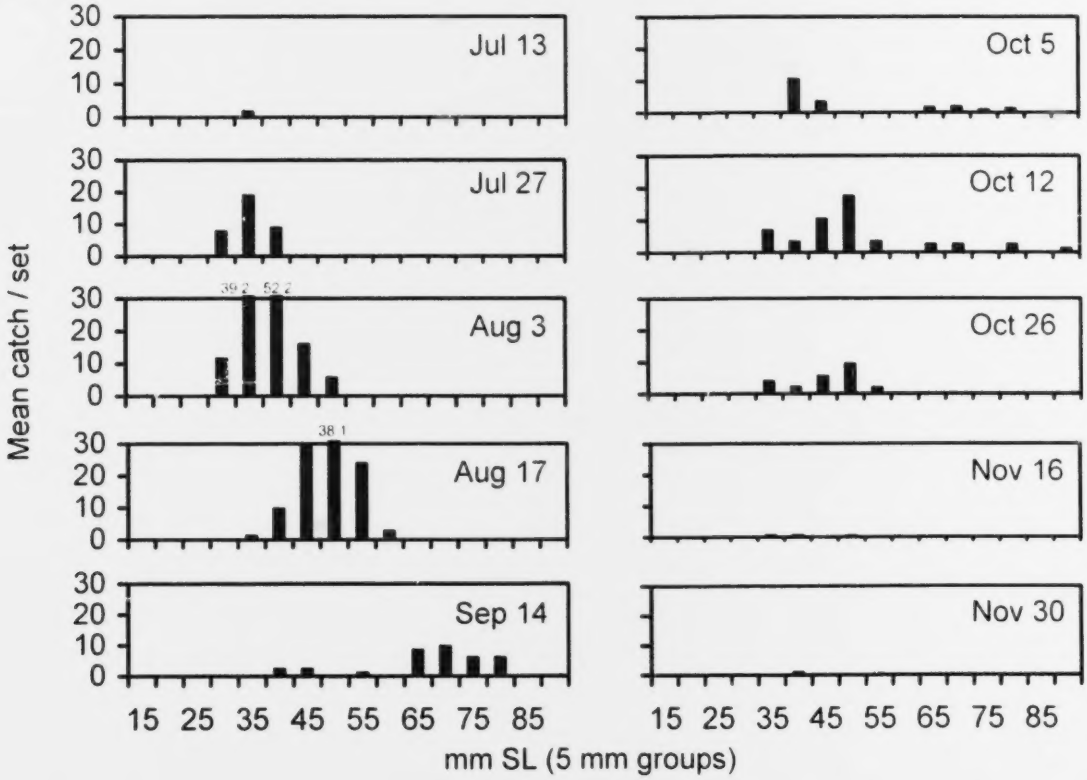

Figure 6 Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound, Bonavista Bay July - November 1999

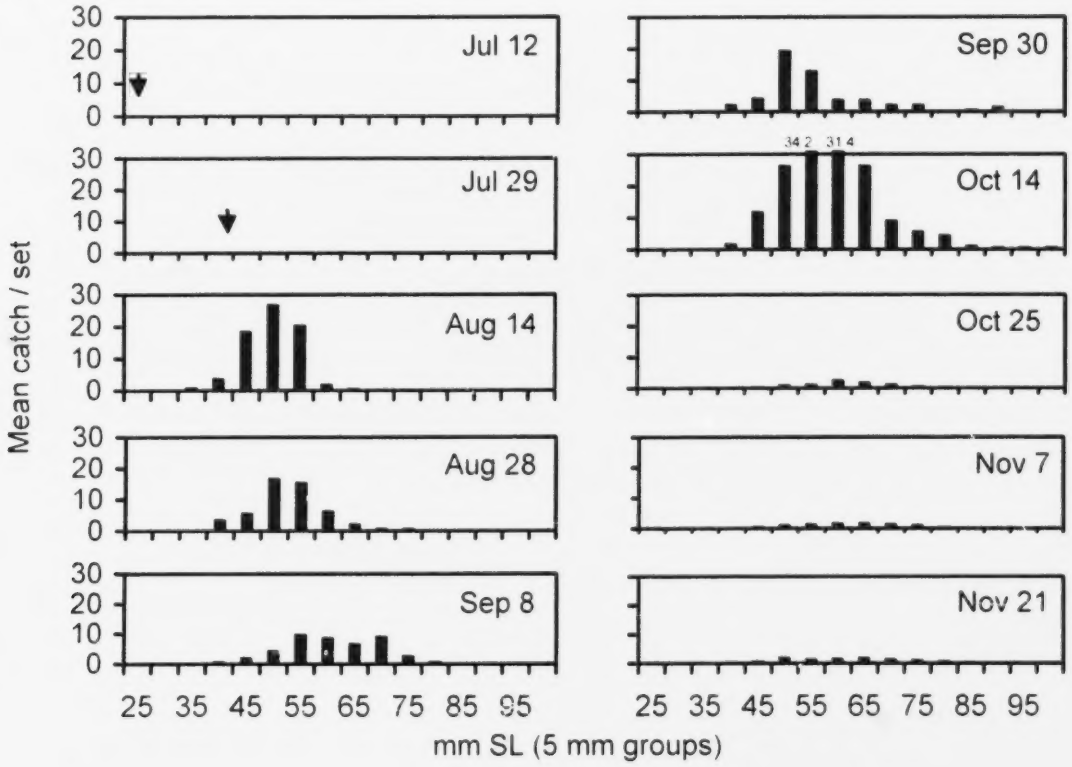

Figure 7 Length frequency of age 0 Atlantic cod caught by nearshore beach seining in Newman Sound Bonavista Bay. July - November 2000

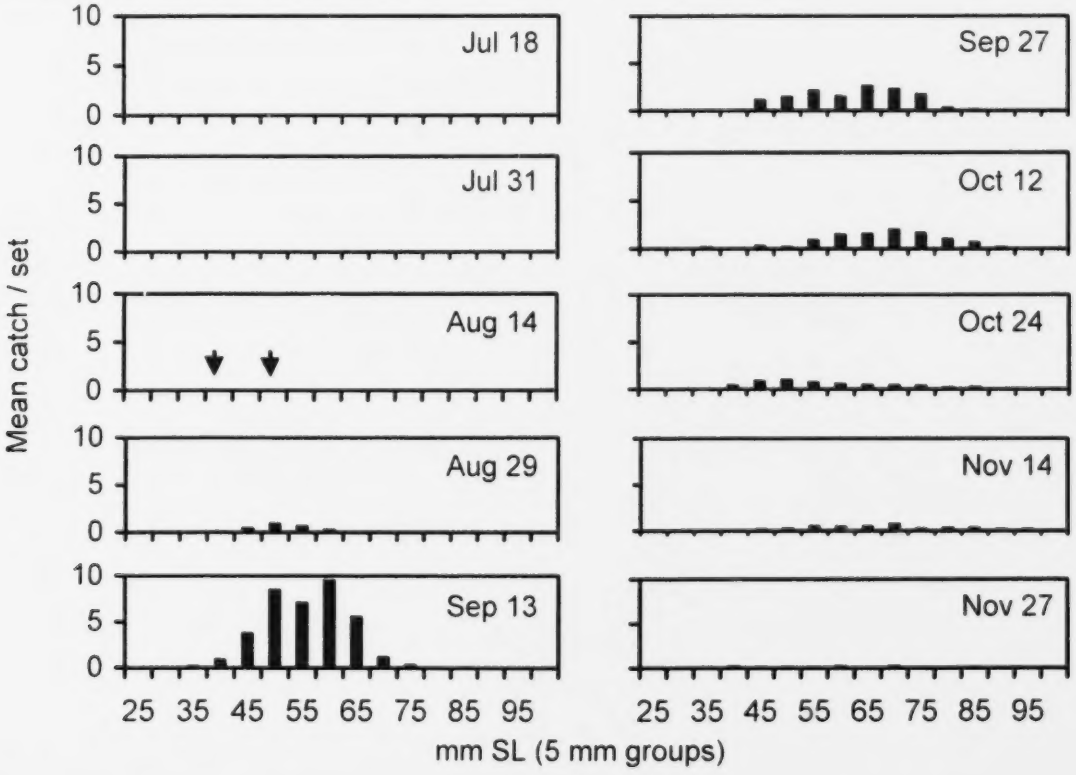

Figure 8. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1996 and their potential age and recruitment pulse structure.

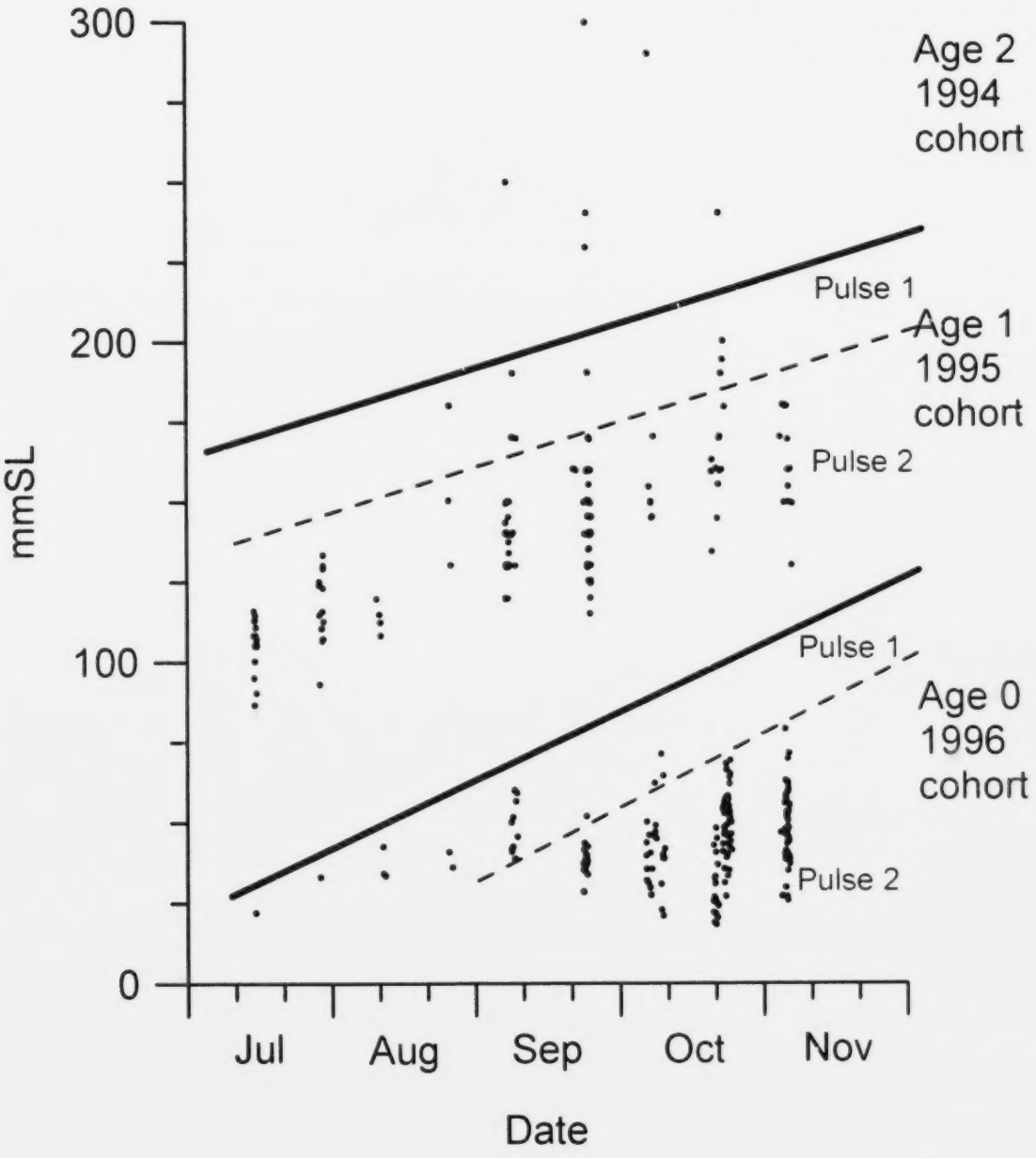

Figure 9. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1998 and their potential age and recruitment pulse structure.

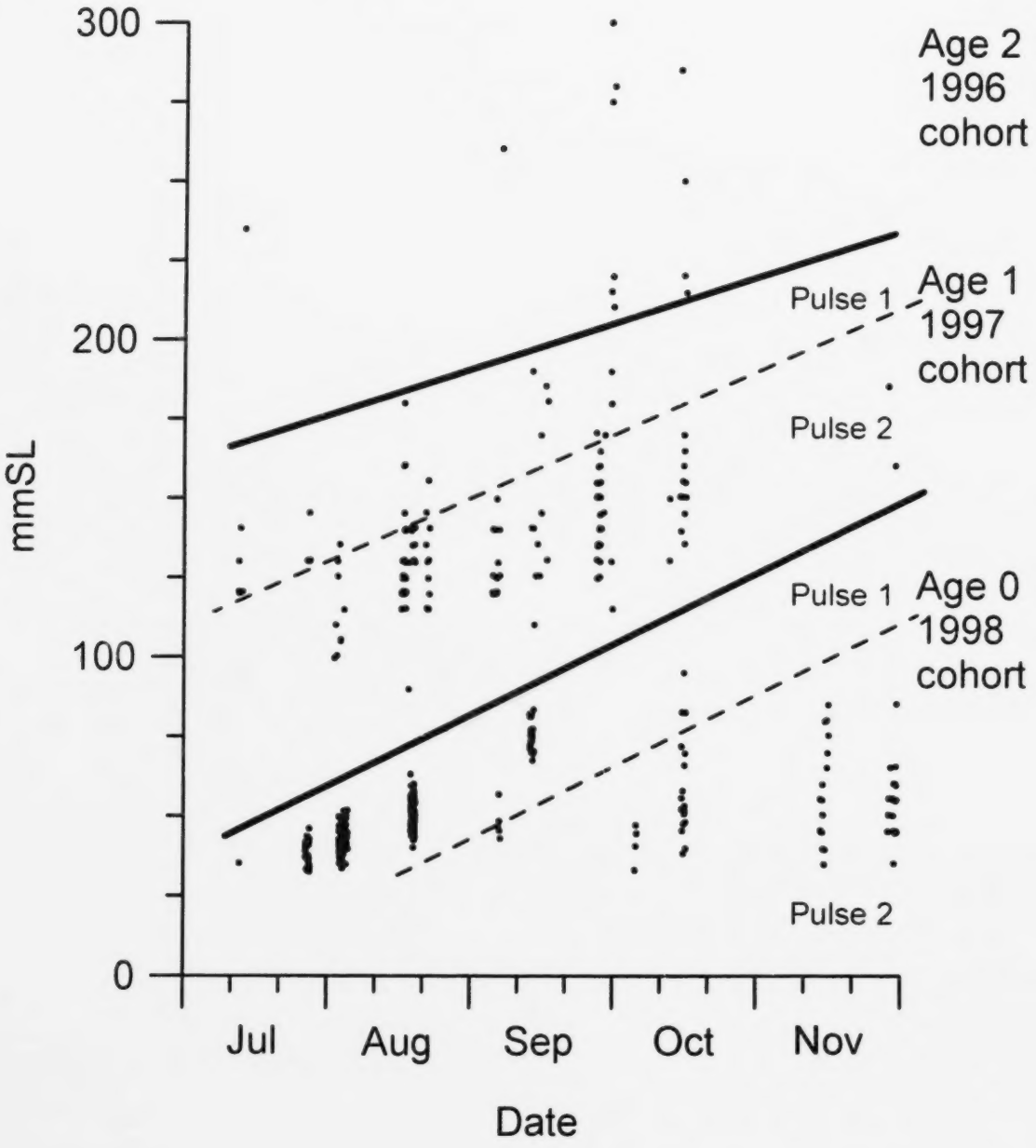

Figure 10. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1999 and their potential age and recruitment pulse structure.

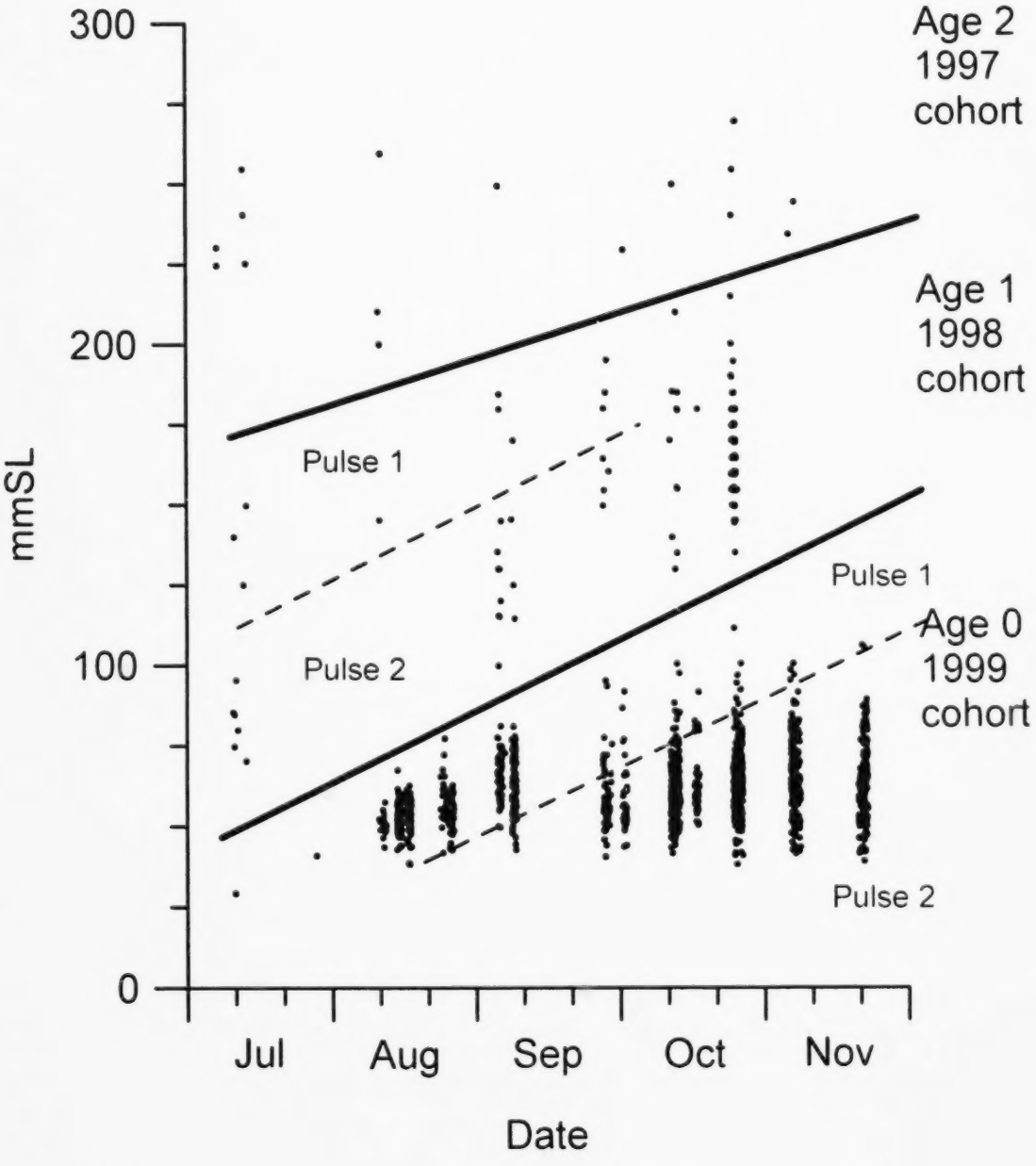

Figure 11. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 2000 and their potential age and recruitment pulse structure.

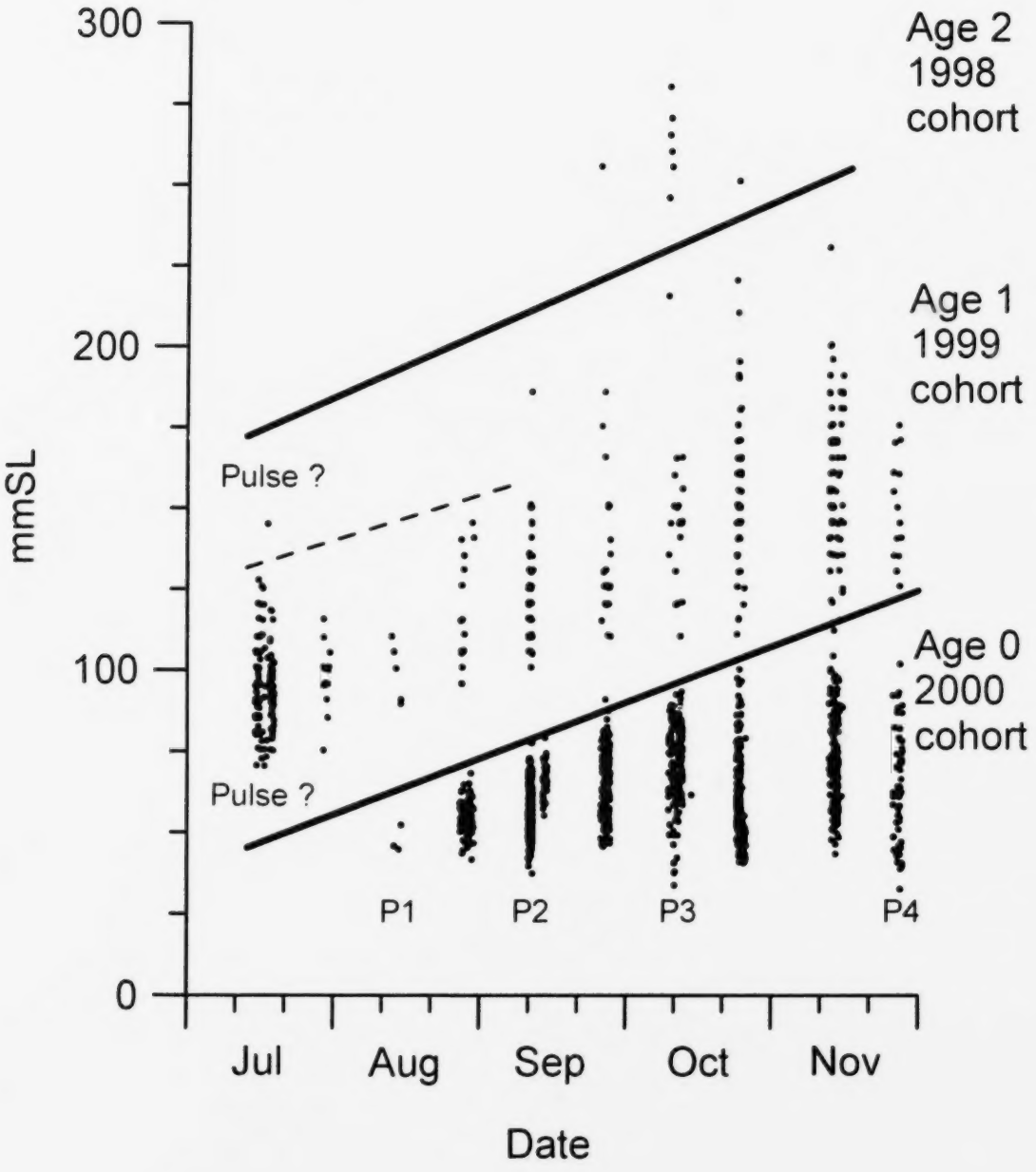

Figure 12. Age 1 Atlantic cod mean catch per seine set in the autumn (mid-September to end-November) during1995-2000